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(71) Applicant(s)
Roger Keith Todd
R.S.T., 125 Lache Lane, CHESTER, CH4 7LU,
United Kingdom

(72) Inventor(s)
Roger Keith Todd

(74) Agent and/or Address for Service
Roger Keith Todd
R.S.T., 125 Lache Lane, CHESTER, CH4 7LU,
United Kingdom

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(54) Abstract Title
A pump

(57) Thermal expansion and contraction of a quantity of gas trapped in a container 17 is used to pump a liquid 18 through the container 17, eg. to water a container plant 24. A controller 3 operates a heater 12, causing heated gas to expand and expel the liquid 18 out through a non-return valve 6 in an outlet pipe 13. The gas contracts as it cools, drawing liquid 18 from a reservoir 20 into the container 17 via a non-return valve 16 in an inlet tube 11. The pump may alternatively operate using solar heat, eg. for land irrigation (Figs 4 and 5), the cooling of the gas being achieved by floating the container 17 in water and raising or rotating it into a shaded position behind sun shields (28,30).

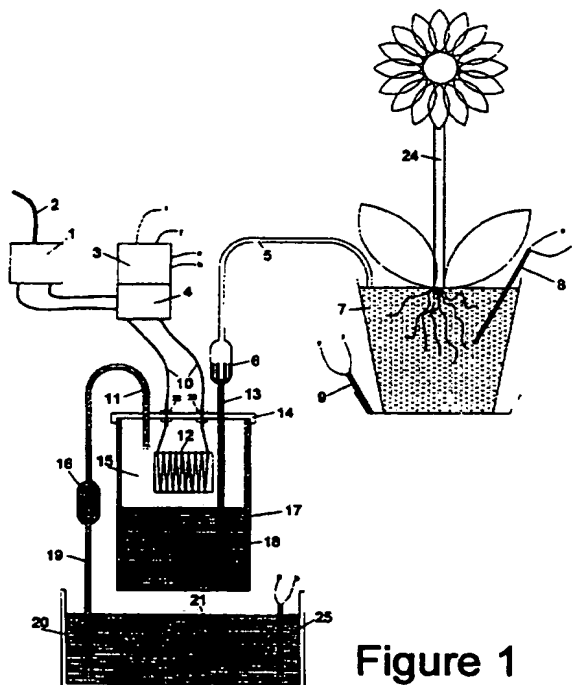
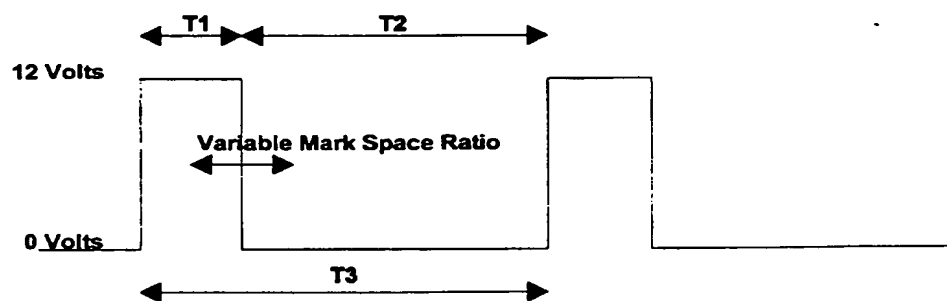


Figure 1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.
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Figure 1



Where T1 = the heating period

Where T2 = the cooling period

Where T3 = the total period.

For a small system T1 will be 2 to 4 minutes and T2 6 to 12 minutes.

Figure 2 (Operation of the Power Generator)

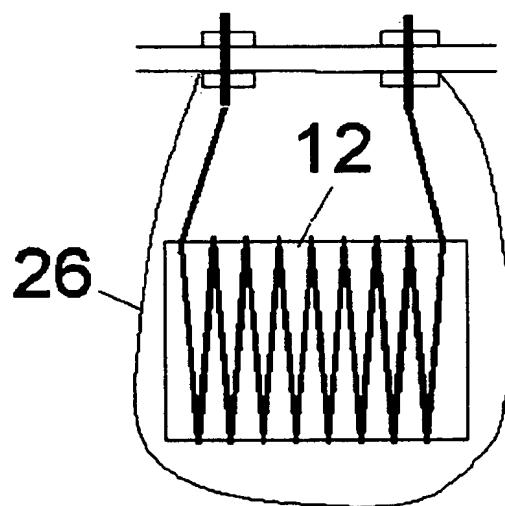
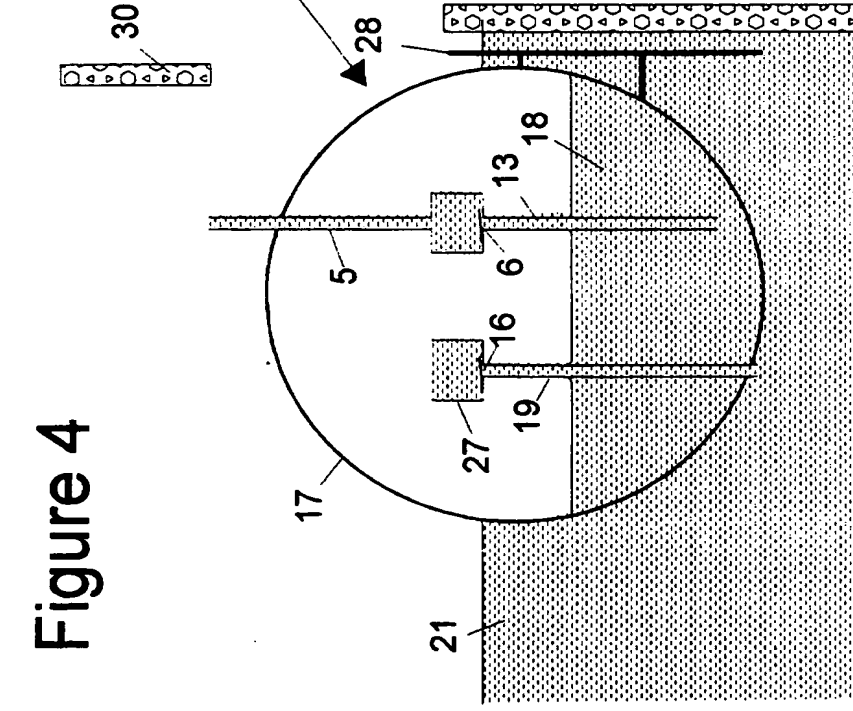
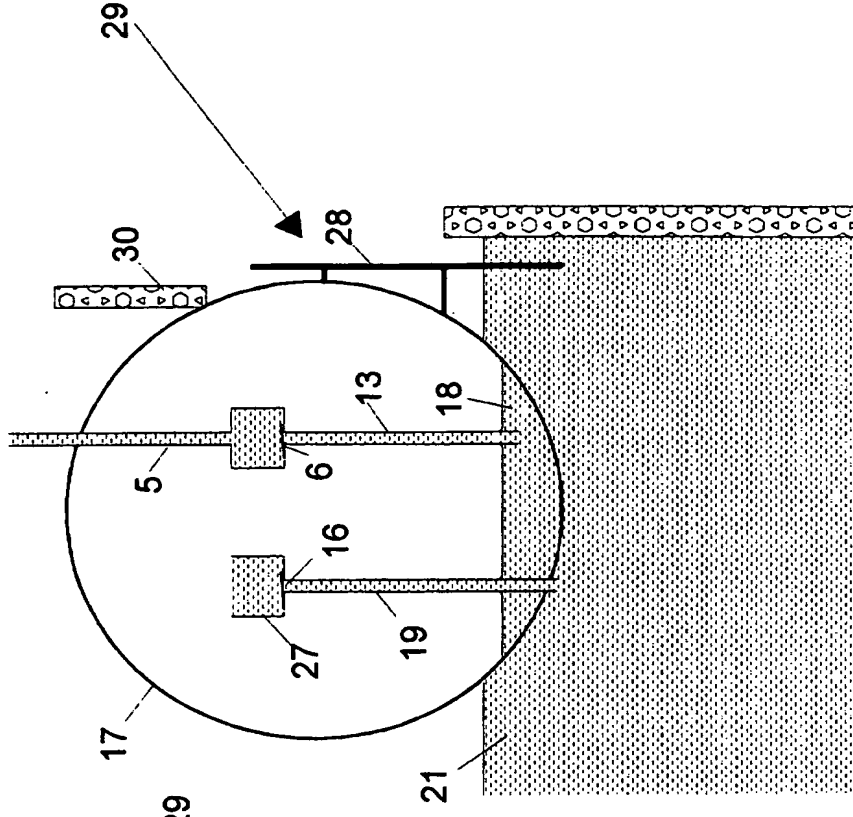


Figure 3 (Gas expansion within a flexible membrane)

Figure 4

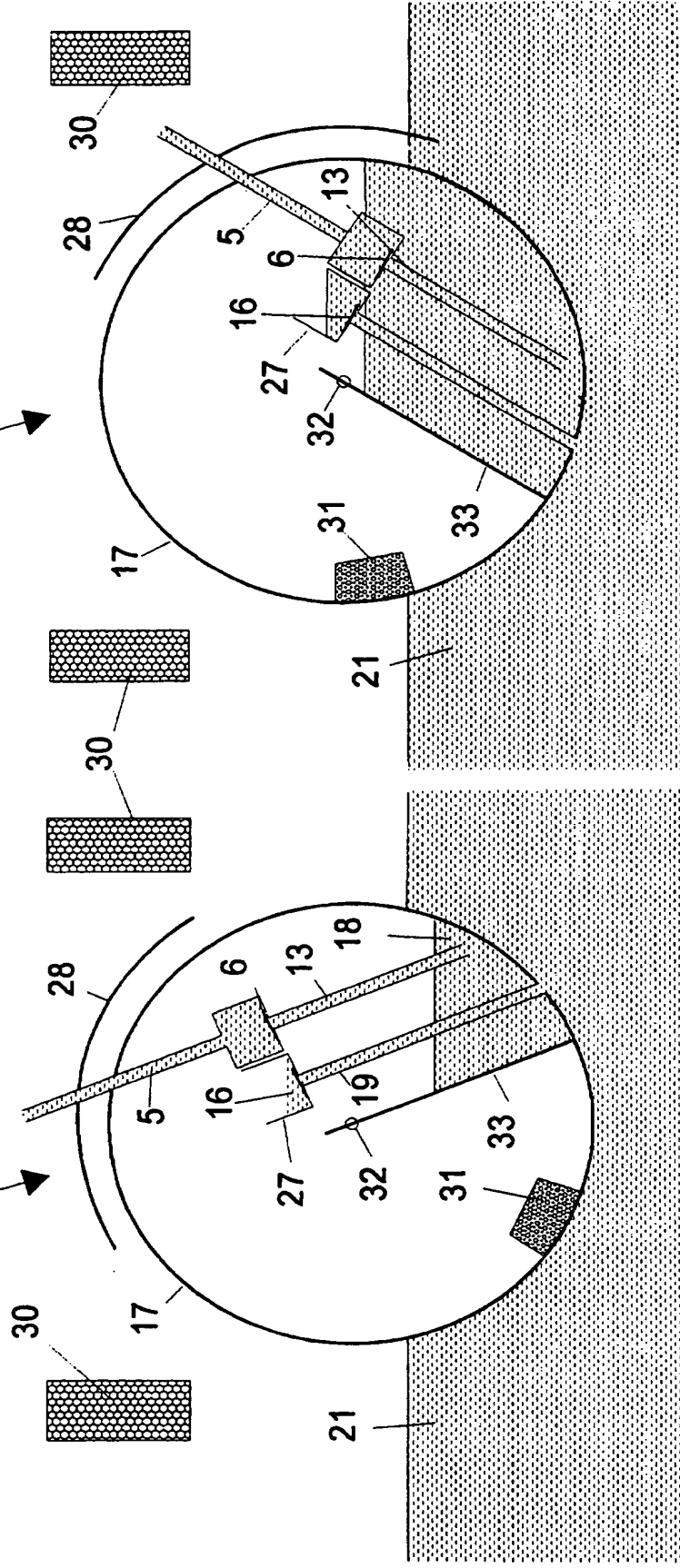


Start of Delivery Stroke



Start of Induction Stroke

29



Start of Induction Stroke

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UK PATENT APPLICATION FOR A CHARLES'S LAW PUMP

1.0 Background of the invention

This invention relates to a family of pumps that use Charles's law which states:

The volume of a given gas, kept at a constant pressure, increases by a constant fraction ($1/273$) of its volume at 0°C . for each degree rise in temperature.

The pumps operate by the heating and cooling of a gas which, in maintaining a constant pressure, expand and contract. The expansion and contraction is used to pump liquids or pumpable powders against gravity.

Variants on this theme are:

- A gas enclosed in a flexible membrane which expands and contracts on heating and cooling of a gas held in the membrane which allows flammable, viscous or corrosive liquids to be pumped.
- A 'third world' variant which uses solar power as the heating agent, uses no electronics and can be built from simple materials.
- Several pumps synchronised to give a continuous flow of liquid.

2.0 Summary of the invention

The invention allows the pumping of liquids against the force of gravity without the use of mechanical diaphragms or pistons.

Non-return valves are used to prevent pumped liquid from flowing back to source on the device recovery and filling stroke.

The object of the device is to provide a simple low cost pump that can be used in many applications requiring a low flow rate of liquid although large units could be capable of delivering many litres of liquid in a short time period.

Typical application are:

- The automatic watering of container grown plants where the facility to inhibit the pump, to prevent over-watering, is include.
- Automatic pump in third world countries to assist in irrigation.
- Pumping of corrosive or viscous liquids
- Delivery of small precise quantities of liquid

3.0 The Pump - Simple heating and cooling (Figure 1)

3.1 Basic free running Operation

Refer to Figure 1. A container (17) is half filled with the liquid (18) to be pumped i.e. water, the remainder of the container is filled with gas i.e. air. The lid (14) is closed which seals the container (17) around the container rim. The heater (12) is activated by an electric current supplied via two feed through electrodes (22) and (23) which are connected to the power generator (4) via connecting leads (10). The heat generated by the heater (12) invokes Charles's law which makes the gas expand by $1/273$ of its volume for each °C it is raised from ambient.

The liquid (18) is forced up the tube (13) into the non-return valve (6), through the valve into the delivery pipe (5) to the point where the liquid is to be delivered. The gas (15) is prevented from exiting tube (11) by the non-return valve (16). The heater is held on for a predetermined time which allows the desired quantity of liquid to be delivered. It is then switched off and the gas in the container (17) allowed to cool.

As the gas cools according to Charles's law, contracting by $1/273$ of its volume for each °C it was raised from ambient. The resulting contraction of the gas will draw liquid (21) stored in the container (20) through the tube (19), through the non-return valve (16) and through the tube (11) into the pump container (17). Liquid can not be pulled back through tube (13) due to the non-return valve (6).

After a recovery period, determined by the power generator (4), the heater (12) is activated and the cycle is repeated.

3.2 Controlled Operation - Example watering of a container plant

The plant (24) draws water from the soil (7) in its container. Water is delivered to the plant (24) by the pump delivery tube (5). The pumping action is controlled by the power generator (4) which in turn is controlled by the system controller (3). The system controller (3) monitors the state of one of the two probes (9) and (8) which connect to the system control (3) by connections (x) and (y). Probe (8) determines the moisture content of the soil and is used to active or inhibit the pump via the system controller (3). Probe (9) determines if water has flowed into the plant container saucer. When water is detected the pump is inhibited by the system controller (3). Either of these two methods can be used to control the pump output. To prevent the pump running dry the probe (25) is monitored by the system controller (3) which will inhibit the pump if the liquid level drops to an unacceptable level.

3.3 Operation of the Power Generator

The power generator (4) runs from a low direct current voltage supplied by a standard commercially available power unit (1) which derives its power from a standard alternating current supply (2). The power generator (4) turns the DC supply into an asymmetric power switching waveform as shown below.

3.4 Flow rates and adjustments

3.4.1 Flow rates

A small system will deliver a few millilitres of liquid per hour. A system suitable for water plant containers 100 millilitres to litres per hour depending on size. The scale is only limited by the physical size of the container. A large system could deliver several hundred litres per hour.

3.4.2 Adjustments

The flow rate is adjusted by altering the mark space ratio of the heating to cooling cycle. This is partially dependent on the ambient temperature around the system and the capacity of the system to transfer heat to the gas. At any time a system will have an optimum flow rate which can be adjusted either manually or by the control unit monitoring ambient temperature and adjusting the Mark Space ratio automatically. The control unit could be replaced by a computer so that monitoring of gas temperature, ambient temperature and power input, precise quantities of liquid can be delivered.

3.5 Heating and Cooling

As the efficiency of the pump depends on first heating the gas and then cooling it, the faster this can be achieved the more efficient the pump becomes. The container (17) and its sealing lid (14) can be made of any material that can be formed into a rigid container. The choice of material is determined by the required characteristics of the pump. The material could range from a good conductor of heat such as a metal to a thermal insulating material such as plastics. Material selection would determine the

operating characteristics of the pump so that it could be tailored for different applications.

3.5.1 Heating

Heating is carried out by passing electricity through a resistive element. To ensure the best heating and circulation of the heated gas the resistive element is shaped into a flat circular loop which is approximately half the diameter of the container. Heated gas will rise by convection and circulate in a dough nut shape pattern. This will heat the gas in the most efficient manner.

3.5.3 Cooling

To rapidly cool the gas the incoming liquid is passed through a small nozzle which causes the liquid to be ejected as a fine spray. This assists in the cooling of the gas.

3.6 Gas expansion within a flexible membrane

Refer to figure 3.

In cases where flammable or corrosive liquids are to be pumped the heater (12) is contained in a flexible membrane (26). The gas in the membrane, upon being heated, would cause the membrane to expand and pump the liquid as defined above. The membrane (26) is a flexible barrier between the heating element and the liquid to be pumped.

4.0 The Pump - Third World Variant (Figure 4 and 5)

This variant is designed to operate without any electronics, use simple readily available materials and require a low level of technology to fabricate. Although it could be made from a wide variety of materials the examples described will use old 40 gallon oil drums, tin cans, small bore (1/2") piping and an old car rubber inner tube. Some assumptions will be made and two variants will be described. This variant can only be used in countries where there are high daily levels of sunshine.

4.1 Construction

Figures 4 and 5 show the oil drum in cross section from one end. The oil drum (17) is fitted with inlet and outlet non-return valves. The inlet valve can draw water (21) through a tube (19) which pierces the drum, through a non-return valve (16) - made from a rubber flap - into an inlet receptacle (27). From here the water can spill into the drum for storage. The water is expelled from the drum by passing up the pipe (13) through the non-return valve (6) and through the outlet pipe (5). The drum is fitted with an external sun shield (28) which is used to block the sun's rays at certain points in the system's operation. Figure 4 operates by the drum moving up and down as the water is transferred in and out. Figure 5 operates by rotating as water is transferred in and out.

6.2 Operation Figure 5

The drum is primed so that it is at the start of the delivery stroke. The drum is then sealed. The outer surface of the drum is painted matt black so that the sun's rays (29) can heat the surface of the drum. As the drum is heated Charles's law is invoked and the water (18) is forced out of the drum through pipe (5). Water and air is prevented from being expelled through pipe (19) by the non-return valve (16). As the water is pumped from the drum the drum rises in the water - it is kept vertical by guides (not shown). As the drum rises the sun shield (28) covers the opening, formed by the water tank base and a fixed shield (30) through which the sun is shining. As the air in the drum cools water is drawn into the drum through pipe (19) and replenishes the internal tank water (18). Non-return valve (6) prevents water being drawn back through the output delivery pipe. The drum will then set up a natural rise and fall rhythm which is determined by the available sun light, capacity of the drum and height to which the water is pumped. To prevent the take off pipe adversely affecting the operation of the system the pumped water would need to be taken off via a supported flexible hose. This variant will operate with sun light shining at angle of 0° to 90° but will be most effective from 30° to 60° so would be of use in terraced hillside locations.

4.3 Operation Figure 5

In this system the same operation as described above is used except the drum oscillates through approximately 45 degrees. The drum can be left to rotate freely or as in the figure it is allowed to rotate about its geometric centre (32). Again the drum is primed so that it is at the start of its delivery stroke and then sealed. In this case the water (18) is partitioned by a barrier (33) the weight of the water acts against a counterweight (31). This rotates the drum so that the sun's rays (29) can heat the top surface of the drum which is painted matt black. As the drum is heated Charles's law is invoked and the water (18) is forced out of the drum through pipe (5). An alternative to a vertical exit for the pipe (5) is to route the pipe through the pivot point (32). Water and air is prevented from being expelled through pipe (19) by the non-return valve (16). As the water is pumped from the drum the drum rotates anti-clockwise so that the sun shield (28) blocks the sun's rays and the drum starts to cool. As the air in the drum

cools water is drawn into the drum through pipe (19) and replenishes the internal tank water (18). Non-return valve (6) prevents water being drawn back through the output delivery pipe. The drum then rotates back towards its original position. The drum will set up a natural oscillation again determined by the available sun light, capacity of the drum and height to which the water is to be pumped.

A variant on this system to not use the central pivot (32) and allow the drum to rotate, rise and fall, in this case the support (30) would be required to keep the drum in position. This variant will be most effective in sun light that shines between 45° and 135°.

In both the above cases an option is to allow the incoming water to spray over the heated drum surface to hasten the cooling of the internal gas

5.0 CLAIMS

1. A container into which liquid is drawn and expelled from by the use of Charles's law, defined as

'The volume of a given gas, kept at a constant pressure, increases by a constant fraction ($1/273$) of its volume at 0°C . for each degree rise in temperature', so that it is pumped against the force of gravity and moved upwards from its source by a distance determined by the expansion of the gas within the container.

2. A container as claimed in Claim 1 which uses electrical, or an other artificial energy, to heat the gas to make it expand.

3. A container as claimed in Claim 1 which uses natural sunlight or any other form of natural energy to heat the gas to make it expand.

4. A container as claimed in Claim 1 and 2 which isolates its heating element from the liquid to be pumped by a flexible membrane.

5. A container as claimed in Claim 1 which is made from any material whether conductive or non-conductive to heat.

6. A container as claimed in Claim 1 and 3 which is caused to rise and fall or rotate by its pumping action.

7. A container as claimed in Claim 1 and 4 which is able to pump corrosive, viscous or flammable liquids.

8. A container as claimed in Claim 1 and 4 which is able to pump fine powders.

9. A container as claimed in Claim 1 with an electronic controller that enables precise volumes of liquid to be delivered.

10. A number of containers as claimed in Claim 1 which are linked sequentially to produce a continuous flow of liquid.



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Claims searched: 1 to 10

Examiner: Robert Crowshaw
Date of search: 25 June 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): A1E (EAE); F1R

Int Cl (Ed.6): A01G 27/00; F04F 1/02, 1/04, 1/06

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	GB 2049822 A (BANBURY) Note page 1 lines 10-19.	1, 2, 3, 5, 7, 8, 10
X	US 4583918 (BAUMBERG) Whole document relevant.	1-7
X	US 4304528 (JORDAN) Whole document relevant.	1, 3, 5, 7
X	US 3902825 (QUILLEN) Whole document relevant.	1, 3, 5, 6, 7
X	US 3898017 (MANDROLAN) Whole document relevant.	1, 2, 5, 7, 9

X Document indicating lack of novelty or inventive step
Y Document indicating lack of inventive step if combined with one or more other documents of same category.

& Member of the same patent family

A Document indicating technological background and/or state of the art.
P Document published on or after the declared priority date but before the filing date of this invention.

E Patent document published on or after, but with priority date earlier than, the filing date of this application.